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DESIGN AND EVALUATION OF SLEEVE NUT THROUGH TENSILE TESTING

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16. Abstract

The Midwest Pooled Fund Program has been developing a prototype of a non-proprietary, high-tension, four-cable, median barrier for use anywhere in a 6H:1V median V-ditch. This system incorporates four evenly-spaced cables, Midwest Weak Posts (MWPs) spaced at 8 to 16 ft (2.4 to 4.9 m) intervals, and a bolted, tabbed bracket to attach the cables to each post. Full-scale crash testing was needed to evaluate the barrier's safety performance. According to the *Manual for Assessing Safety Hardware* 2016 (MASH 2016) testing matrix for cable barriers installed within a 6H:1V median V-ditch, a series of eight full-scale crash tests are required to evaluate the safety performance of a system.

Previous full-scale tests conducted on this system have indicated potential cable snag on the cable bracket nuts and exposed threaded studs. Cable snagging can limit vertical cable movement and post deflection, which could then lead to significant occupant compartment deformation and penetration, and therefore failed tests. Consequently, new nut designs were investigated for use with the cable brackets in attempt to eliminate cable snagging. Tensile testing was performed on multiple sleeve nut prototypes and all were deemed acceptable.

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UNCERTAINTY OF MEASUREMENT STATEMENT

The Midwest Roadside Safety Facility (MwRSF) has determined the uncertainty of measurements for several parameters involved in standard full-scale crash testing and non-standard testing of roadside safety features. Information regarding the uncertainty of measurements for critical parameters is available upon request by the sponsor and the Federal Highway Administration. Test nos. HTSN-1 through HTSN-14 were non-certified component tests conducted for research and development purposes only and are outside the scope of the MwRSF's A2LA Accreditation.

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1 INTRODUCTION

1.1 Background

In recent years, the Midwest Pooled Fund Program has been developing a non-proprietary, high-tension, four-cable, median barrier in cooperation with the Midwest Roadside Safety Facility (MwRSF) [1]. This cable barrier system was intended for use anywhere within a 6H:1V median V-ditch and consisted of four cables supported by Midwest Weak Posts (MWPs) spaced at 8-ft (2.4-m) intervals. A bolted, tabbed bracket was utilized to attach the lower three cables on alternating sides of the MWPs, while a brass keeper rod was utilized to contain the top cable within a V-notch cut into the top of the posts.

Previously, this cable barrier system was subjected to eight full-scale crash tests in accordance with the *Manual for Assessing Safety Hardware* (MASH) 2009 and 2016 [2-3]. Test nos. MWP-1 and MWP-2, in accordance with MASH 2009 test designation nos. 3-17 and 3-11, respectively, successfully captured and contained the vehicle [1]. For test no. MWP-3, the post spacing was changed to 8 ft (2.4 m) to evaluate the system deflections and working width with tighter post spacing. Ultimately, the test failed due to vehicle rollover [1].

Modifications were made to improve the system performance, which required further full-scale crash testing to evaluate the crashworthiness of the system according to the MASH 2009 Test Level 3 (TL-3) criteria [2]. Test no. MWP-4 was conducted in accordance with MASH 2009 test designation no. 3-11 and utilized a 10-ft (3.0-m) post spacing to establish the working width associated with a reduced post spacing. During the test, the 2270P pickup truck was initially captured and redirected by cable nos. 2 and 4. However, the vehicle eventually overrode cable no. 2 after the vehicle was parallel with the system [4]. Test no. MWP-5 was invalidated due to technical difficulties, and thus was not reported on.

Test no. MWP-6, conducted in accordance with MASH 2009 test designation no. 3-10, utilized 8-ft (2.4-m) post spacing placed on level terrain. During the test, the occupant compartment was penetrated when the top of the posts were overridden, causing tears in the floor pan in two locations. Thus, test no. MWP-6 was determined to have failed the safety performance criteria corresponding to MASH 2009 test designation no. 3-10 [4].

To reduce the likelihood of occupant compartment penetration, the top corners of the MWP were rounded. The outer corners were radiused ⅝ in. (16 mm), and the inner bent corners were filleted ¼ in. (6 mm). Test no. MWP-7 was a repeat of test no. MWP-6, but with the modified MWP. During the test, the floor pan was again torn due to contact with the tops of the MWPs as the vehicle overrode them. Four separate tears occurred. Thus, test no. MWP-7 was determined to have failed the safety performance criteria corresponding to MASH 2009 test designation no. 3-10 [4]. These performance issues highlighted the need to develop new barrier components to improve the safety performance of the cable median barrier.

After a series of 21 bogie tests, a modified post was designed to mitigate the floor pan tearing [5]. Test no. MWP-8 was conducted on the modified barrier system, consisting of MWPs with rounded top edges and ¾-in. (19-mm) diameter weakening holes at the ground line. This test was conducted according to MASH 2016 test designation no. 3-10 [6]. The vehicle was contained by the system, and no floor pan tearing was observed throughout the initial two vehicle crossover events across the barrier and posts. During the third impact series with the posts, one post penetrated the occupant compartment, which resulted in floor pan tearing in two locations. Therefore, test no. MWP-8 was deemed unacceptable.

An investigation into protecting the free edges at the top of the post included adding a cap to the top of the posts to reduce the propensity for post penetration into the occupant compartment and floor pan. A total of five bogie tests were conducted to evaluate several cap designs and post modifications [7]. From the bogie test results, a two-part cap with a single retainer bolt added to the top of the posts was expected to shield the free edges of the top of the MWP during post-to-vehicle contact and mitigate the floor pan tearing.

Analysis of the test results for test no. MWP-9 [8] showed that the system adequately contained and redirected the 1100C vehicle with controlled lateral displacements of the barrier. There were no detached elements or fragments that showed potential for penetrating the occupant compartment or presented undue hazard to other traffic. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements were deemed acceptable because they did not adversely influence occupant risk safety criteria nor cause rollover. However, cable no. 3 snagged on the top cap retainer bolt and nut and induced an increased downward and lateral force to the vehicle's A-pillar. This action caused cable nos. 3 and 4 to become interlocked with the A-pillar on the impact side of the vehicle, resulting in excessive lateral A-pillar crush of 3.4 in. (86 mm), which is greater than the 3-in. (76-mm) lateral MASH 2016 limit. Additionally, the left-front side window shattered due to contact with cable nos. 1 and 2, which is unacceptable when the A- or B-pillar crush exceeds the MASH 2016 limit of 3 in. (76 mm). Tearing and penetration did not occur to the vehicle's floor pan. Thus, the two-part cap designed for this test was able to mitigate the floor pan tearing and post penetration into the occupant compartment, but the test was ultimately deemed unsuccessful due to excessive A-pillar crush and the shattering of the left-front side window.

During the nine full-scale tests on the cable barrier design, which included a bolted, tabbed bracket, the cables would release from the brackets and then slide up the post. Evidence from previous testing indicated potential snag on the nut and end of the bolt. Therefore, a need arose to investigate a new nut design for use with the bolted tabbed bracket.

1.2 Objective

The objective of this research was to design and evaluate a new nut design to mitigate potential cable snag on the non-proprietary, four-cable, median barrier.

1.3 Scope

The research objective was achieved through completion of several tasks. Investigation and design of two prototype sleeve nuts for tabbed brackets was conducted. After the prototype nuts were fabricated, tensile testing was performed on each concept. Results were analyzed, evaluated, and documented. Conclusions and recommendations were then made pertaining to the safety performance of the newly-designed sleeve nuts.

2 SLEEVE NUT DESIGN

2.1 Sleeve Nut Design

All sleeve nuts were fabricated from AISI 1144 Class B Stressproof steel rod, with nominal yield and ultimate strengths of 100 ksi (689 MPa) and 115 ksi (792 MPa), respectively. Two different overall lengths, head shapes, and threaded lengths were investigated. The inner and outer diameters were the same for all sleeve nuts and measured $^5/_{16}$ in. (8 mm) and 0.563 in. (14 mm), respectively. The effects of plain and corrosion-resistant finishes were also investigated. Examples of the different parameters are shown in Figure 1. The test matrix is shown in Table 1. Detailed drawings are shown in Appendix A.

Figure 1. Illustration of Differences between Sleeve Nut Concepts

The two different head shapes were designed to be low profile in order to mitigate cable snag and reduce the possibility of floor pan tearing. Both sleeve nuts were designed to develop nominal yield and tensile forces of 5.2 kips and 6.0 kips (23.1 kN and 26.7 kN), respectively. These values are near the minimum nominal yield and tensile strength of the $^5/_{16}$-in. (8-mm) diameter Grade 5 bolt, which are 92 ksi and 120 ksi (634.3 MPa and 827.4 MPa), respectively. This corresponds to a yield and tensile force capacity of 4.8 kips and 6.3 kips (21.4 kN and 28.0 kN), respectively, for the $^5/_{16}$-in. (8-mm) diameter bolt. The bolted connection is necessary to maintain the fixity of the tabbed bracket, and provide positive engagement between the tab bracket and post.

Table 1. Test Matrix, Test Nos. HTSN-1 through HTSN-14

Test Name	Bolt			Sleeve Nut					Maximum Tensile Force (kip)	Failure Mechanism
	Finish	Diameter (in.)	Length (in.)	Head Shape	Length (in.)	Tap	Threaded Depth (in.)	Finish		
HTSN-1	Plain	$^{5}/_{16}$	5	Dome	1.576	Regular	0.750	Plain	7.34	Bolt fracture
HTSN-2	Plain	$^{5}/_{16}$	5	Dome	1.576	Regular	0.750	Plain	7.40	Bolt fracture
HTSN-3	Plain	$^{5}/_{16}$	5	Dome	1.391	Regular	0.625	Plain	7.37	Bolt fracture
HTSN-4	Plain	$^{5}/_{16}$	5	Dome	1.391	Regular	0.625	Plain	7.39	Bolt fracture
HTSN-5	Plain	$^{5}/_{16}$	5	Cone	1.391	Regular	0.625	Plain	7.39	Bolt fracture
HTSN-6	Plain	$^{5}/_{16}$	5	Cone	1.391	Regular	0.625	Plain	7.39	Bolt fracture
HTSN-7	Ecoguard	$^{5}/_{16}$	5	Cone	1.391	Oversize	0.625	Plain	6.74	Bolt fracture
HTSN-8	Ecoguard	$^{5}/_{16}$	5	Dome	1.391	Oversize	0.625	Plain	6.85	Bolt fracture
HTSN-9 (Baseline)	Plain	$^{5}/_{16}$	5	Regular $^{5}/_{16}$ nut				Plain	7.34	Bolt fracture
HTSN-10	No bolt, used MTS base (Gr.8)			Cone	1.391	Regular	0.625	Plain	N/A	Test jig thread fracture
HTSN-11	Ecoguard	$^{5}/_{16}$	5	Dome	1.391	Oversize	0.625	Galvanized	6.81	Bolt fracture
HTSN-12	Ecoguard	$^{5}/_{16}$	5	Dome	1.391	Oversize	0.625	Galvanized	6.97	Bolt fracture
HTSN-13	Ecoguard	$^{5}/_{16}$	5	Cone	1.391	Oversize	0.625	Galvanized	6.74	Bolt fracture
HTSN-14	Ecoguard	$^{5}/_{16}$	5	Cone	1.391	Oversize	0.625	Galvanized	7.00	Bolt fracture

2.2 Test Conditions

For each test, a $^{5}/_{16}$-in. (8-mm) diameter Grade 5 bolt was threaded into the sleeve nut until it was snug. Typically, engagement of three threads between a bolt and nut will develop between 75 and 90 percent of the bolt strength. Therefore, one full bolt diameter deep into the sleeve nut should develop the full strength of the bolt. Each test used either a plain or a corrosion-resistant finish, as shown Table 1. The bolt and nut combinations were attached to test jigs mounted between grips of an MTS Criterion Series 60 – Model 64.106 machine, as shown in Figure 2. Pre-test photographs of the nuts and bolts are shown in Figures 3 through 6. A quasi-static tension test was conducted by slowly separating the grips of the tensile testing machine, thus creating a tensile force in the bolt and nut, until failure occurred. A total of fourteen static component tests were conducted, as shown in Table 1.

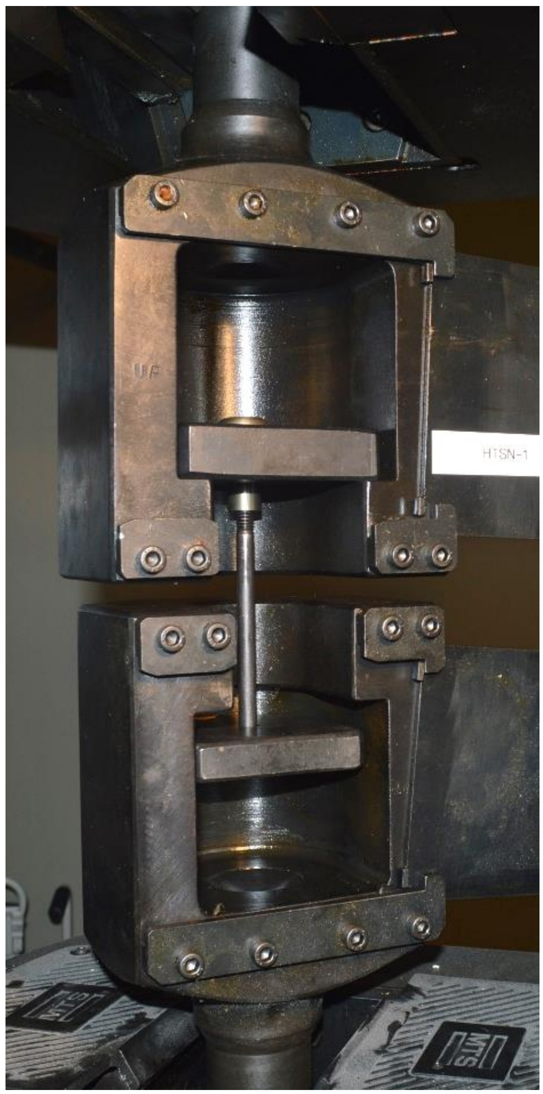
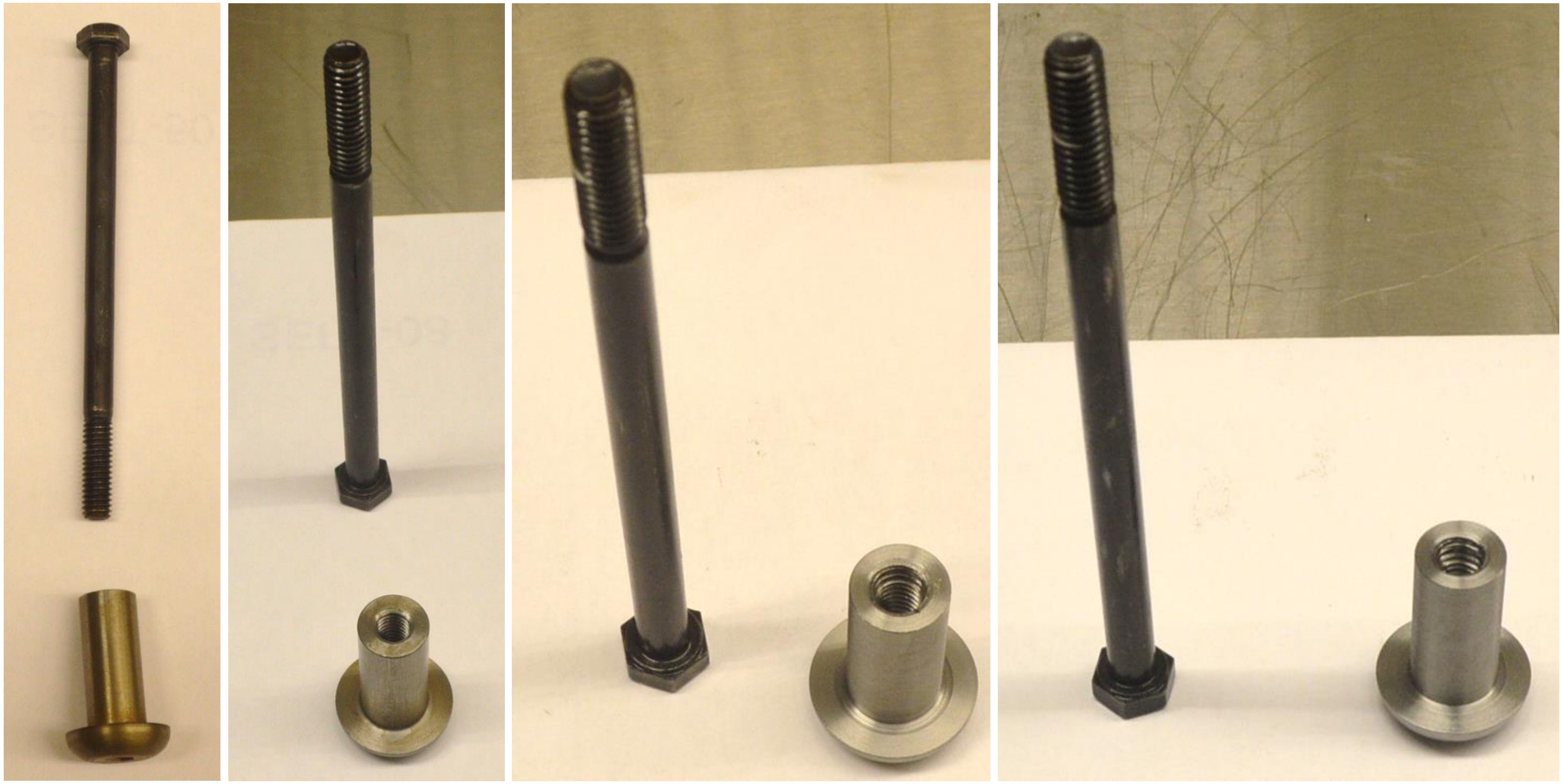


Figure 2. Tensile Test Setup



HTSN-1 HTSN-2 HTSN-3 HTSN-4

Figure 3. Pre-Test Bolts and Nuts, Test Nos. HTSN-1 through HTSN-4

Figure 4. Pre-Test Bolts and Nuts, Test Nos. HTSN-5 through HTSN-8

HTSN-9

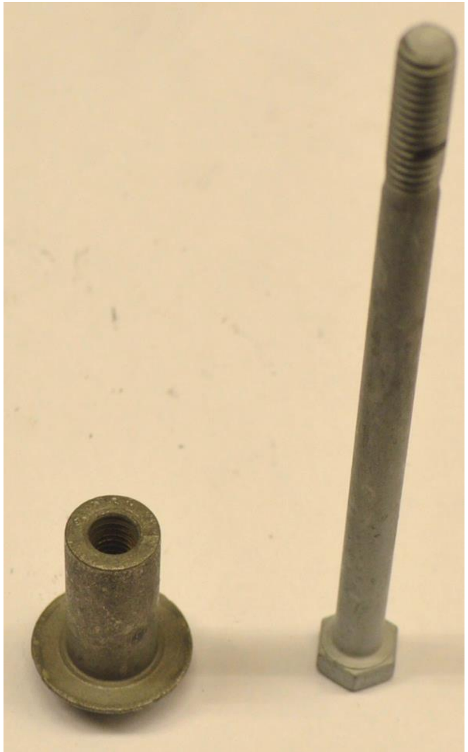
HTSN-10

HTSN-11

HTSN-12

Figure 5. Pre-Test Bolts and Nuts, Test Nos. HTSN-9 through HTSN-12

HTSN-13



HTSN-14

Figure 6. Pre-Test Bolts and Nuts, Test Nos. HTSN-13 and HTSN-14

2.3 Test Results

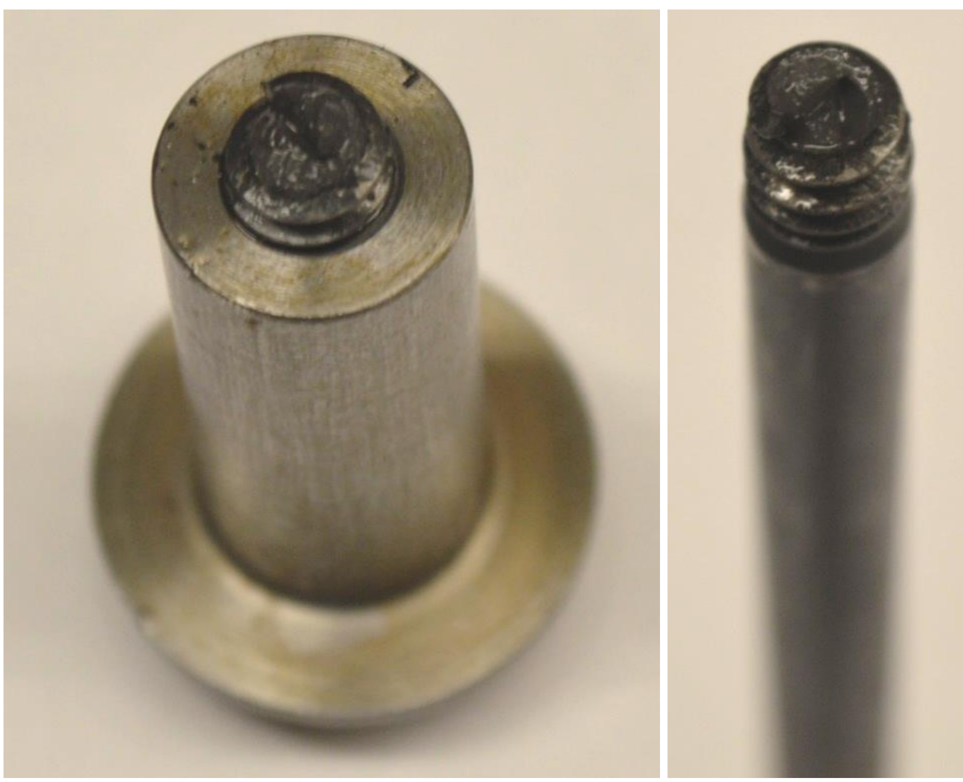
The variables in each test, test nos. HTSN-1 through HTSN-14, were the parameters of the bolts and nuts, as shown in Table 1. In every test, the $^{5}/_{16}$-in. (8-mm) diameter Grade 5 bolt failed before the sleeve nut. Photographs of the bolt and nut damage for each test are shown in Figures 7 through 10.

During the initial round of testing (test nos. HTSN-1 through HTSN-6), the sleeve nut length, threaded depth, and head shape were investigated. The longer sleeve nut and deeper thread length did not make a difference in the test results. In addition, the two different head shapes did not make a difference. Therefore, all remaining tests were conducted on the shorter sleeve nut with shallower thread length. However due to the availability of head shapes of the existing sleeve nuts, both the dome and cone heads continued to be evaluated.

All nut and bolt combinations developed strength beyond the expected bolt strength, as shown in Figure C-1. The pre-loading in the sample shown in Figure C-2 was due to tension in the locking mechanism of the MTS Criterion that was meant to hold the sample in place for the test.

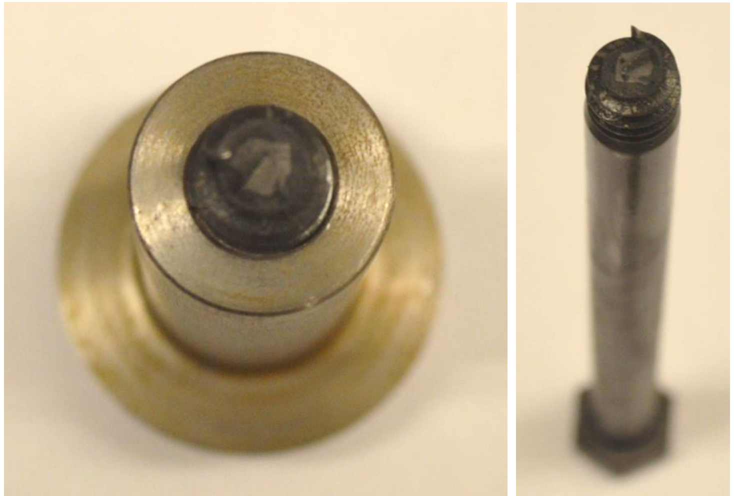
After each test, the sleeve nuts were inspected for damage, markings, or permanent deformation. For each test condition, the sleeve nuts and threads remained undamaged. The fractured portion of the bolt remaining in the sleeve nut could be easily removed without any plastic damage to the threads. No differences in test results were observed based on nut galvanization or head shape.

HTSN-1

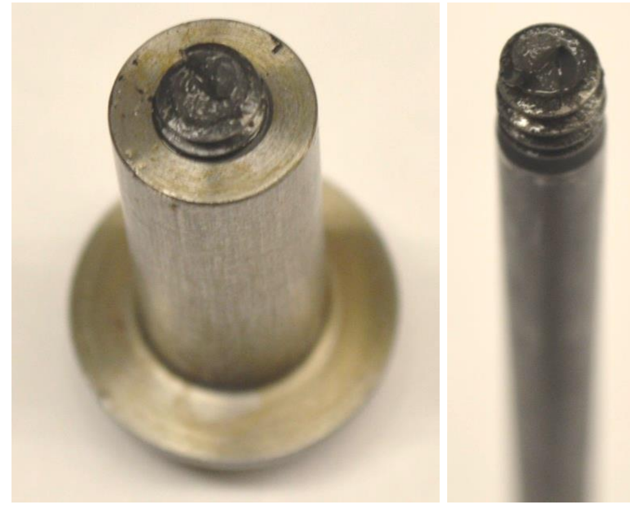


HTSN-2

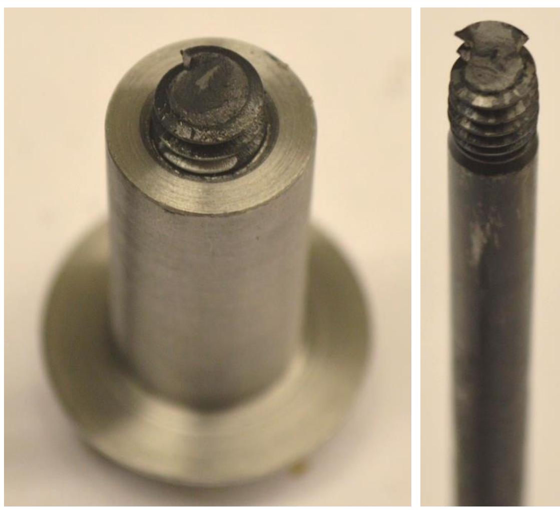
Figure 7. Post-Test Bolts and Nuts, Test Nos. HTSN-1 and HTSN-2



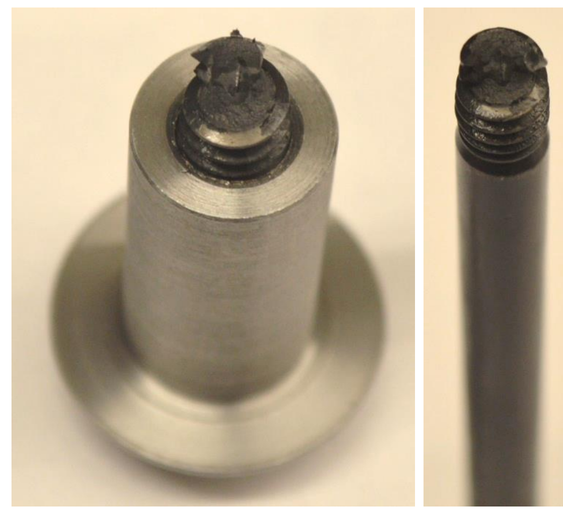
HTSN-3



HTSN-4

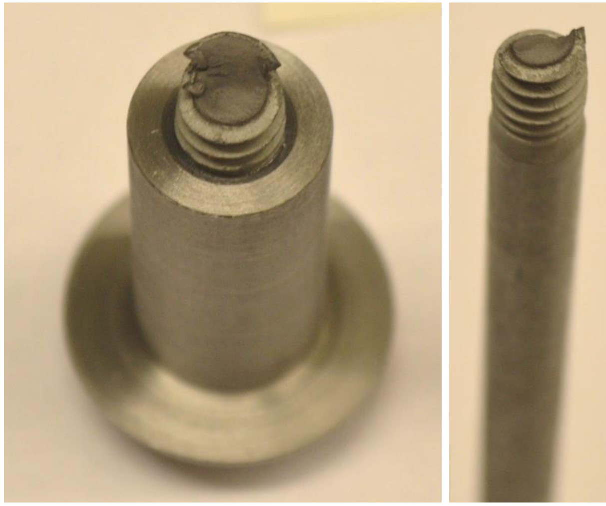


HTSN-5

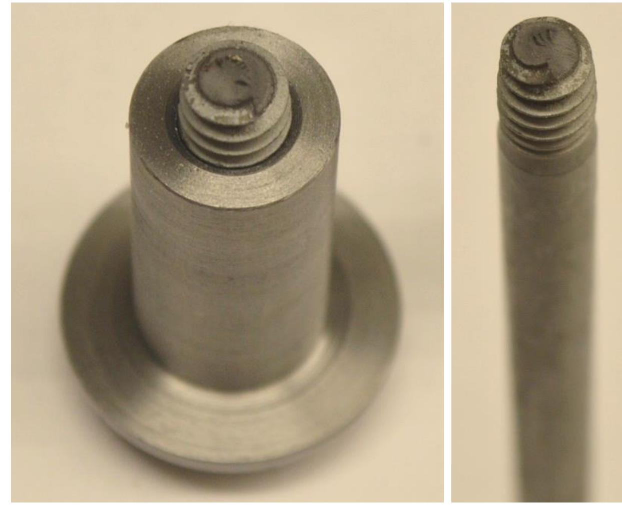


HTSN-6

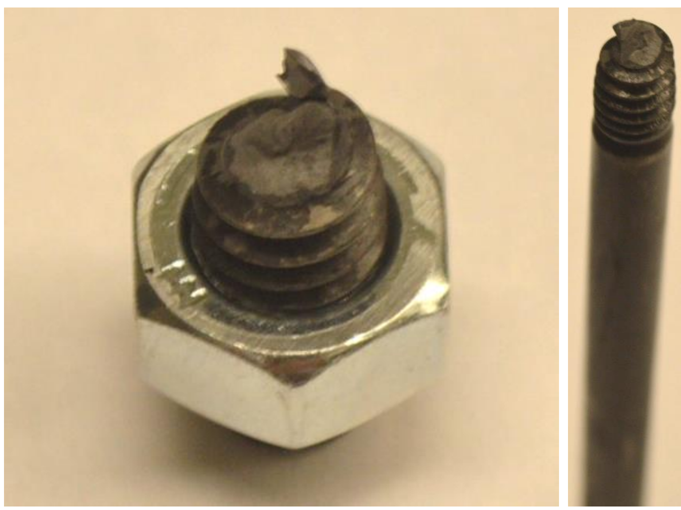
Figure 8. Post-Test Bolts and Nuts, Test Nos. HTSN-3 through HTSN-6



HTSN-7



HTSN-8

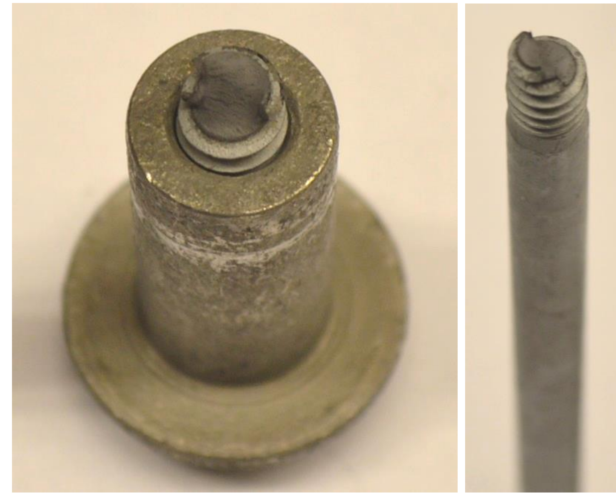


HTSN-9

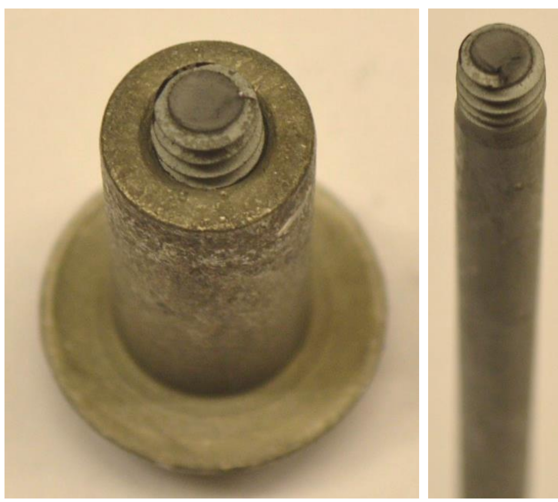
HTSN-10

Figure 9. Post-Test Bolts and Nuts, Test Nos. HTSN-7 through HTSN-10

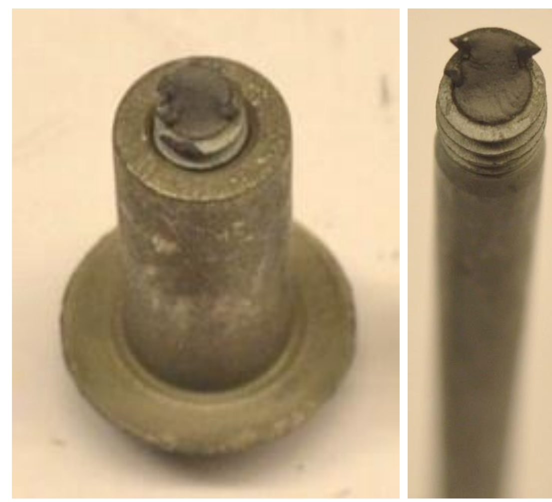
HTSN-11



HTSN-12



HTSN-13



HTSN-14

Figure 10. Post-Test Bolts and Nuts, Test Nos. HTSN-11 through HTSN-14

3 CONCLUSIONS AND RECOMMENDATIONS

Based on the test results, all sleeve nut designs herein were determined to be acceptable. Each configuration developed the full tensile capacity of the $^5/_{16}$-in. (8-mm) diameter Grade 5 bolt, which was 6.3 kips (28.0 kN) nominally. Also, according to ASTM A563 [9], mixing finishes is not recommended. Therefore, a corrosion resistant sleeve nut should only be used with a corrosion resistant bolt. The recommended final nut designs are shown in Figures 11 and 12.

In order to allow for a galvanized finish, the sleeve nut threads need to be oversized. It is left to the fabricator to determine the amount of oversizing that is required and necessary for accommodating a corrosion-resistant, $^5/_{16}$-in. diameter, ASTM A307 or Grade 5 bolt.

Typically, engagement of three threads between a bolt and nut will develop between 75 and 90 percent of the bolt strength. Therefore, one full bolt diameter deep into the sleeve nut should develop the full strength of the bolt. In addition, the bolt length will be designed such that a maximum number of threads will be engaged between the bolt and the sleeve nut when utilized in the cable median barrier system design (i.e., bolt threaded into sleeve nut the entire threaded portion of the sleeve nut).

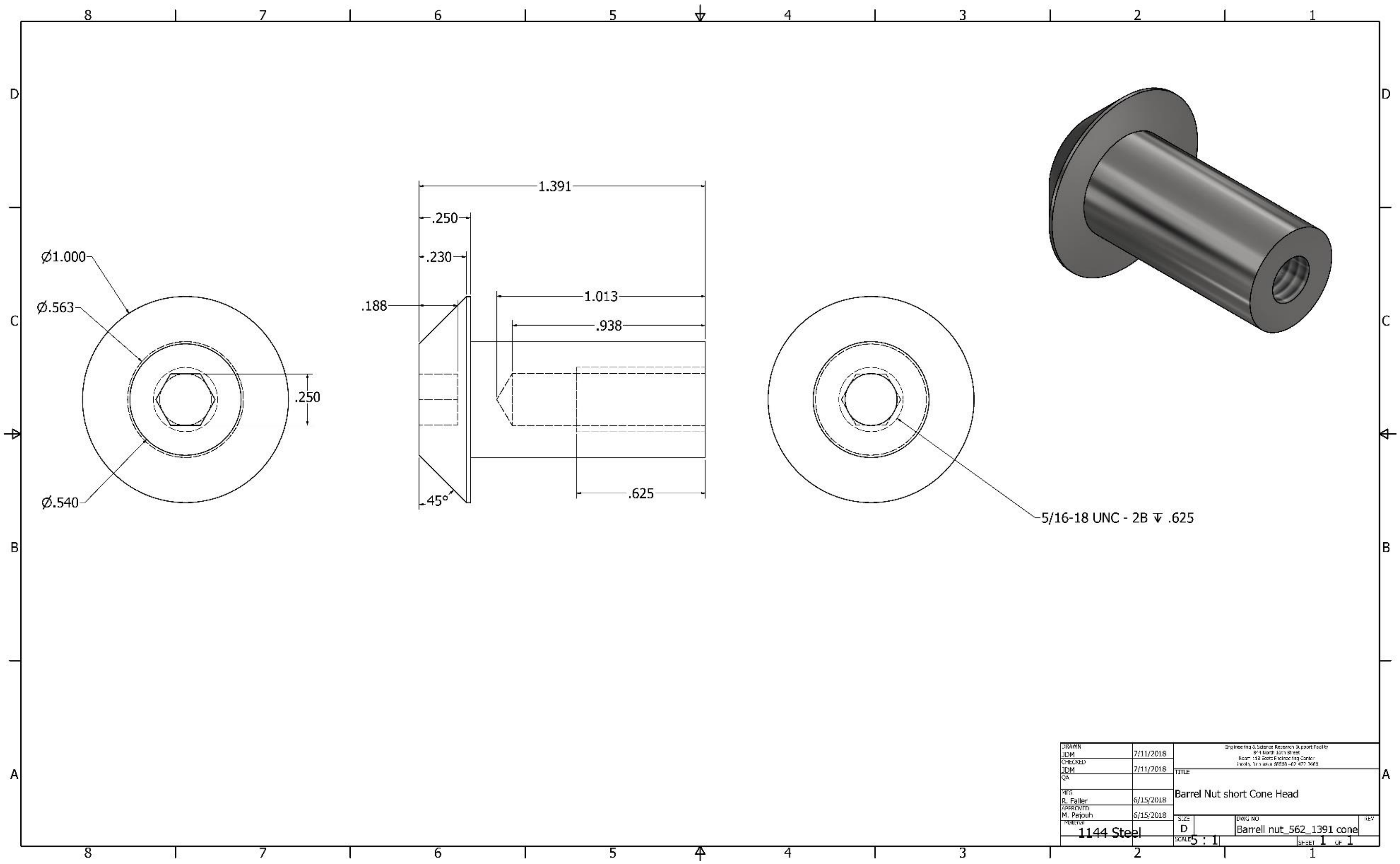


Figure 11. Recommended Barrel Nut with Cone Head Design

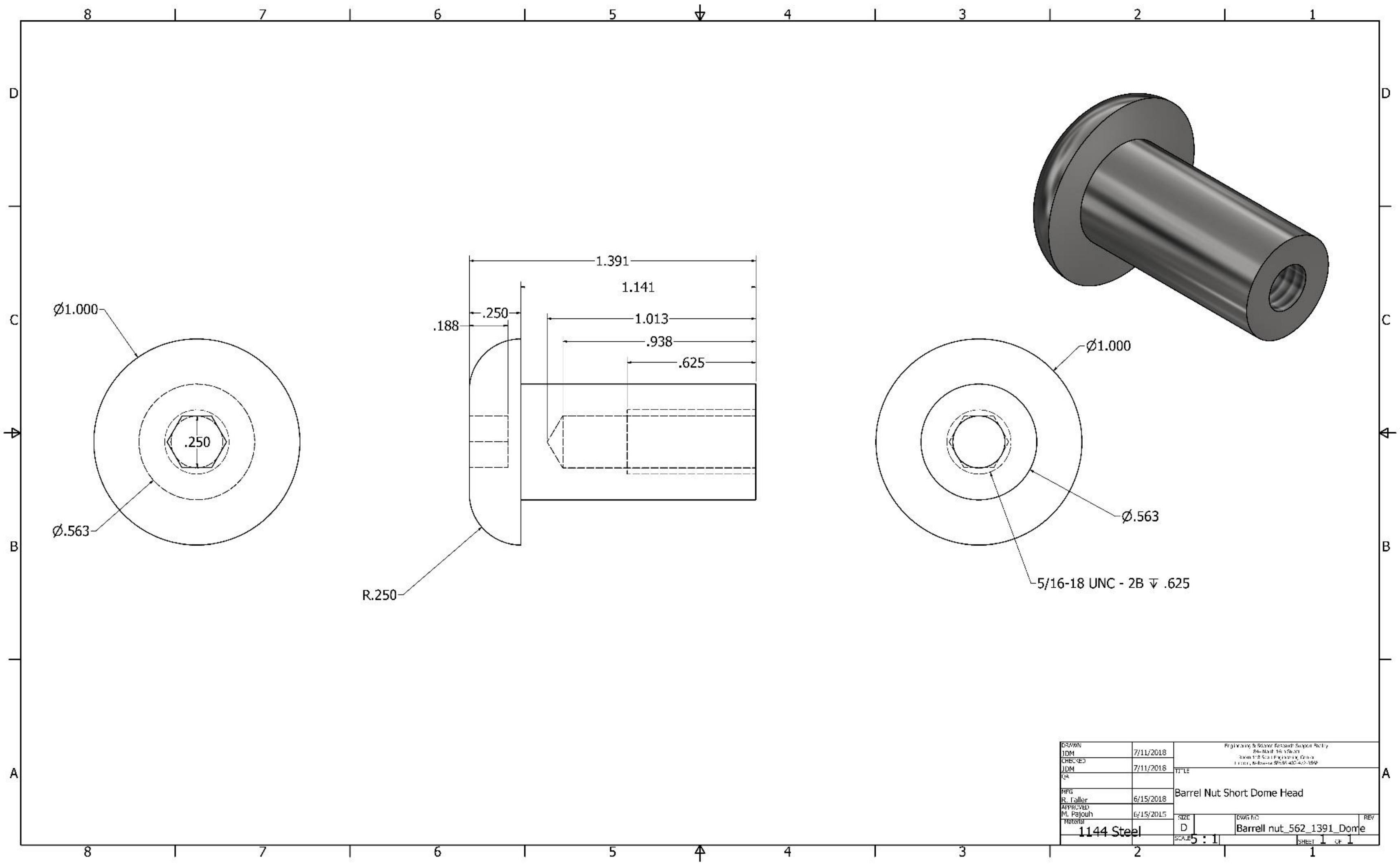


Figure 12. Recommended Barrel Nut with Dome Head Design

4 REFERENCES

1. Bielenberg, R.W., Rosenbaugh, S.K., Faller, R.K., Humphrey, B.M., Schmidt, T.L., Lechtenberg, K.A., and Reid, J.D., *MASH Test Nos. 3-17 and 3-11 on a Non-Proprietary Cable Median Barrier*, Report No. TRP-03-303-15, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, November 3, 2015.

2. *Manual for Assessing Safety Hardware*, American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C., 2009.

3. *Manual for Assessing Safety Hardware, Second Edition*, American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C., 2016.

4. Kohtz, J.E., Bielenberg, R.W., Rosenbaugh, S.K., Faller, R.K., Lechtenberg, K.A., and Reid, J.D., *MASH Test Nos. 3-11 and 3-10 on a Non-Proprietary Cable Median Barrier*, Report No. TRP-03-327-16, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, May 17, 2016.

5. Rosenbaugh, S.K., Hartwell, J.H., Bielenberg, R.W., Faller, R.K., Holloway, J.C., and Lechtenberg, K.A., *Evaluation of Floor Pan Tearing and Cable Splices for Cable Barrier Systems*, Report No. TRP-03-324-17, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, May 16, 2017.

6. Meyer, D.T., Lechtenberg, K.A., Faller, R.K., Bielenberg, R.W., Rosenbaugh, S.K., and Reid, J.D., *MASH Test No. 3-10 of a Non-Proprietary, High-Tension, Cable Median Barrier for Use in 6H:1V V-Ditch (Test No. MWP-8)*, Report No. TRP-03-331-17, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, May 10, 2017.

7. Meyer, D.T., Asadollahi Pajouh, M., Lechtenberg, K.A., Faller, R.K., Bielenberg, R.W., and Holloway, J.C., *Phase II Evaluation of Floor Pan Tearing for Cable Barrier Systems*, Report No. TRP-03-359-18, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, March 30, 2018.

8. Asadollahi Pajouh, M., Lechtenberg, K.A., Faller, R.K., Holloway, J.C. Bielenberg, R.W., Rosenbaugh, S.K., and Reid, J.D., *MASH Test No. 3-10 of a Non-Proprietary, High-Tension, Cable Median Barrier for Use in 6H:1V V-Ditch (Test No. MWP-9)*, Report No. TRP-03-412-19, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, N, March 30, 2018.

9. *A563-15 Standard Specification for Carbon and Alloy Steel Nuts*, ASTM International, West Conshohocken, Pennsylvania, 2015.

5 APPENDICES

Appendix A. Drawings

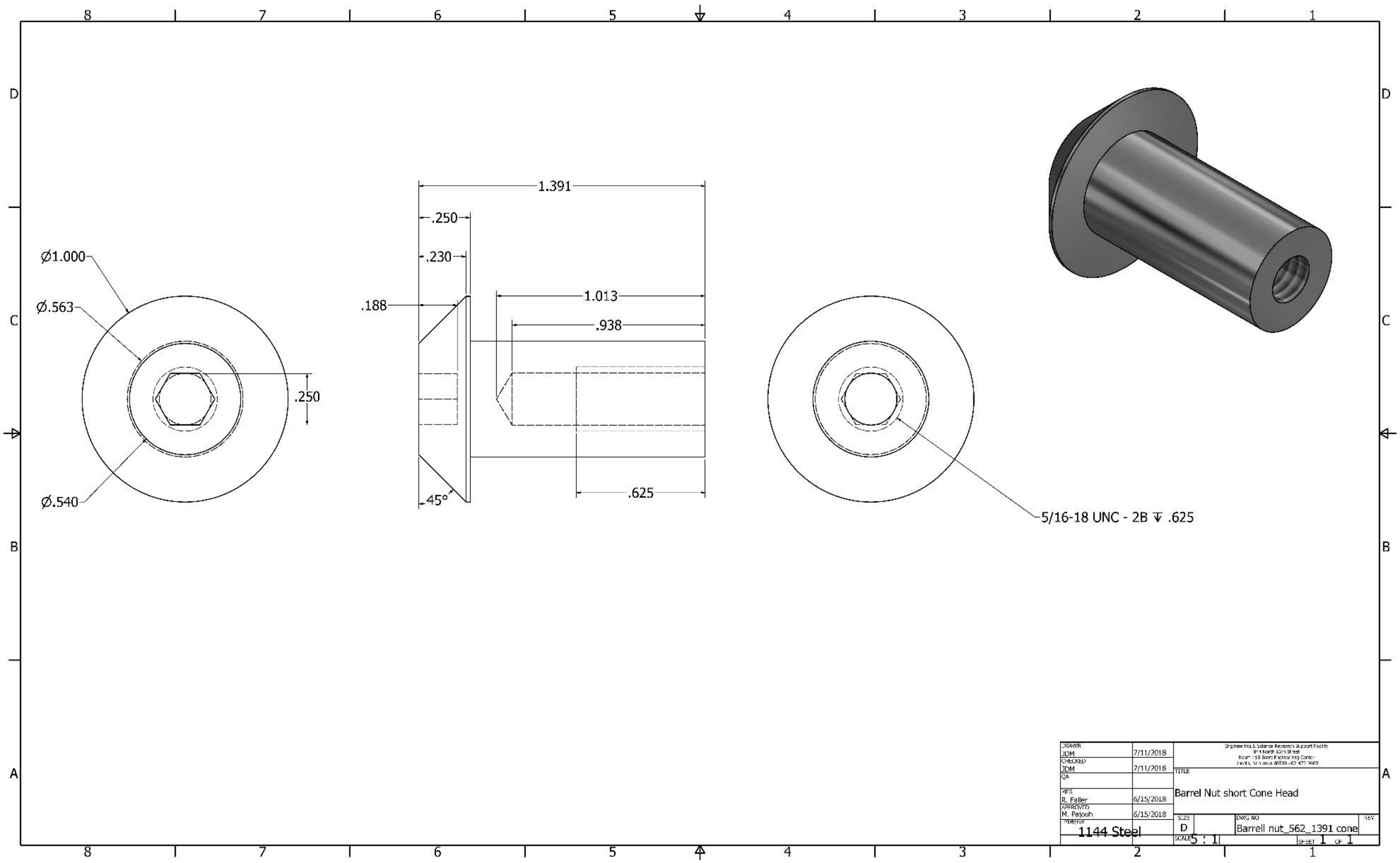


Figure A-1. 1.391-in. (35-mm) Long Barrel Nut with Cone Head Design

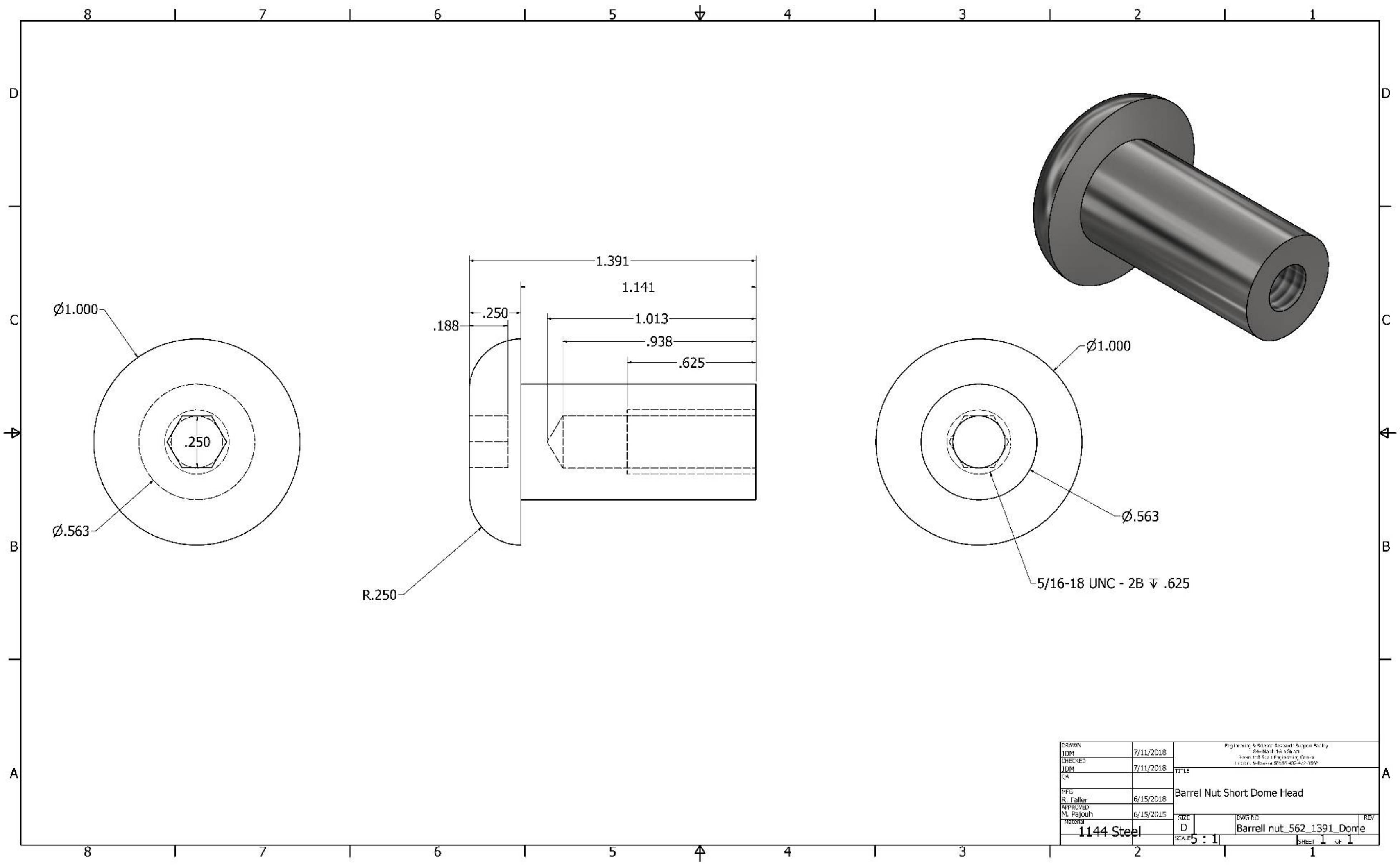


Figure A-2. 1.391-in. (35-mm) Long Barrel Nut with Dome Head Design

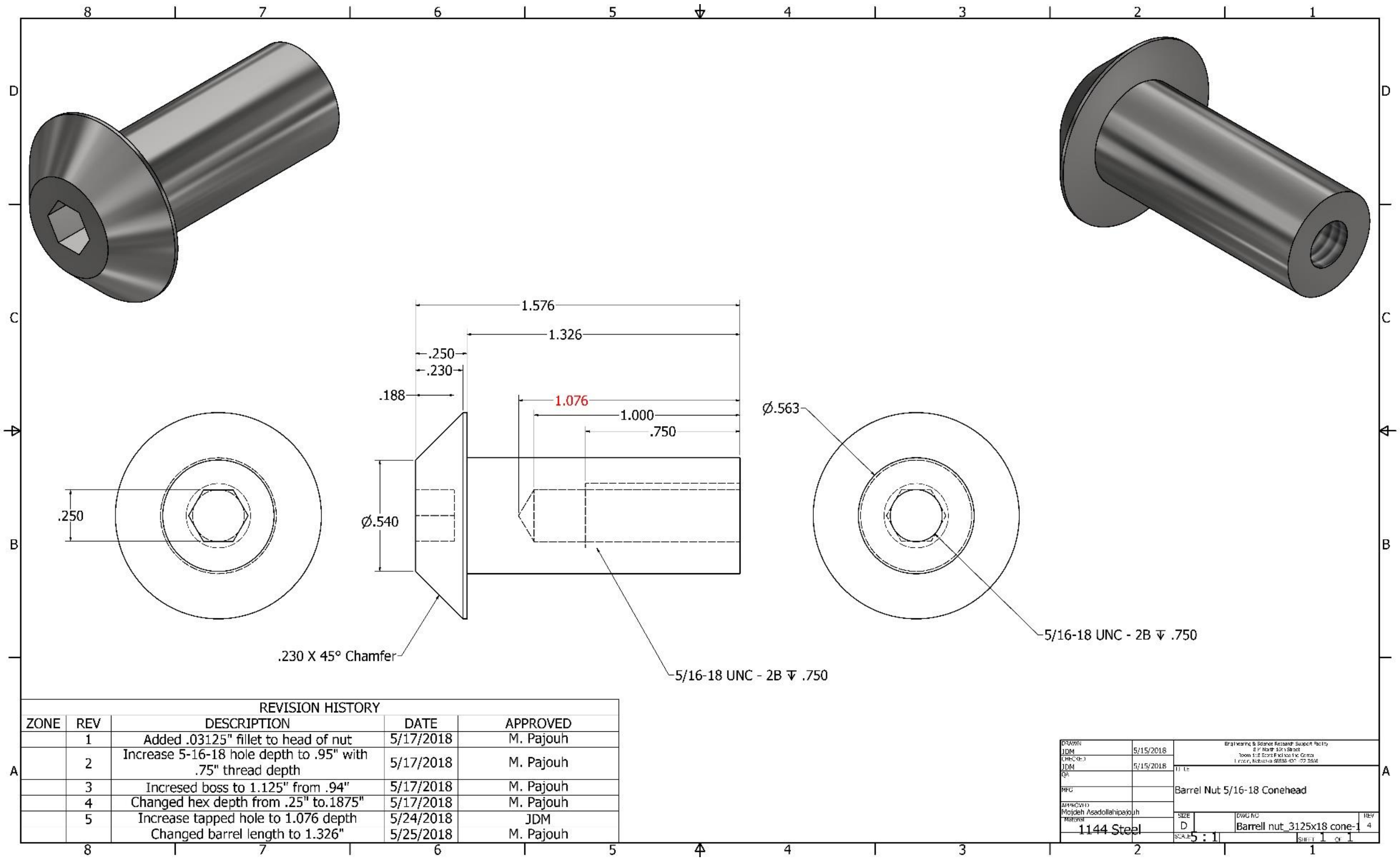


Figure A-3. 1.567-in. (40-mm) Long Barrel Nut with Cone Head Design

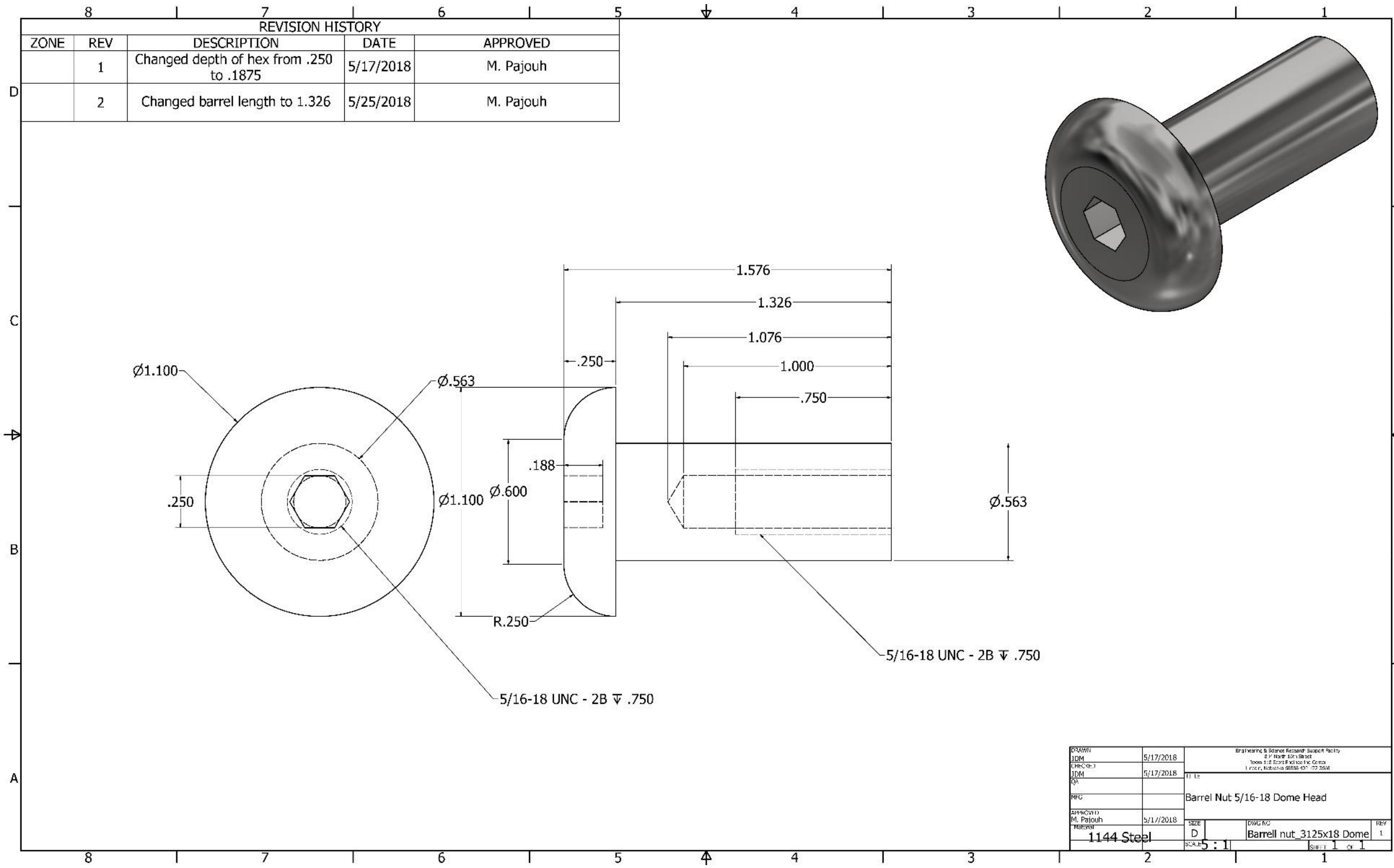


Figure A-4. 1.576-in. (40-mm) Long Barrel Nut with Dome Head Design

Appendix B. Material Specifications

Table B-1. Bill of Materials, Test Nos. HTSN-1 through HTSN-14

Description	Material Specification	Reference No.
$^{5}/_{16}$-in. (8-mm) Dia. Sleeve Nut	AISI 1144 Class B Stressproof Steel	Correspondence
$^{5}/_{16}$-in. (8-mm) Dia. Plain Hex Head Bolt	SAE J429 Gr. 5	T#220023859 P#12073
$^{5}/_{16}$-in. (8-mm) Dia. Ecoguard Hex Head Bolt	SAE J429 Gr. 5	H#XG40ACR

From: James McManis
Sent: Tuesday, May 15, 2018 12:26 PM
To: Mojdeh Asadollahipajouh
Subject: Another steel option

Mojdeh,

See the following option for the barrel nut raw material. I estimate that the raw material cost from 1144 steel for the design you submitted to me yesterday is .45 cents each. Of course that too would reduce depending on the quantity of the order. I'll send you a quote with the 1144 steel material shortly. Once you have provided me with your other designs I can generate additional quotations as well.

1144 (Stressproof-equivalent) steel

This material is actually a good possibility for your barrel nut application. It has a higher-strength alloy than 1018 or A36, but in addition has improved ductility as well. The chief feature of 1144 steel, however, is that it has very low distortion or warpage after machining due to a combination of its chemistry, method of manufacture, and heat treatment. Finally, 1144 is relatively easy to machine, with a machinability rating of 83% of AISI 1212 steel.

1144 (Stressproof-equivalent) steel		
Minimum Properties	Ultimate Tensile Strength, psi	115,000
	Yield Strength, psi	100,000
	Elongation	8.0%
	Rockwell Hardness	B95 / C17
Chemistry	Iron (Fe)	97.54 - 98.01%
	Carbon (C)	0.4 - 0.44%
	Manganese (Mn)	1.35 - 1.65%

Regards,
Jim

James D. McManis, Mgr.
844 North 16th Street
Room 118A Scott Engineering Center
Engineering & Science Research Support Facility
University of Nebraska – Lincoln
Lincoln, Nebraska USA 68588-0642
Phone 402-472-2555
Fax 402-472-0442

From: James McManis
Sent: Wednesday, July 11, 2018 11:40:45 AM
To: Mojdeh Asadollahipajouh
Subject: RE: Documents

Mojdeh,

The materials is 115K strength.

Jim

James D. McManis, Mgr.
844 North 16th Street
Room 118A Scott Engineering Center
Engineering & Science Research Support Facility
University of Nebraska – Lincoln
Lincoln, Nebraska USA 68588-0642
Phone 402-472-2555
Fax 402-472-0442
Email: jmcmanis1@unl.edu
Web: http://engineering.unl.edu/research/esrsf-engineering-science-research-support-facility/

Figure B-2. $^{5}/_{16}$-in. (8-mm) Dia. Sleeve Nut Material Certification

FASTENAL®

Certificate of Compliance

Sold To:

UNL TRANSPORTATION

Purchase Order: 4Cable Bolt Lab Testing

Job: 4Cable Bolt Lab Testing

Invoice Date: 07/06/2018

THIS IS TO CERTIFY THAT WE HAVE SUPPLIED YOU WITH THE FOLLOWING PARTS.
THESE PARTS WERE PURCHASED TO THE FOLLOWING SPECIFICATIONS.

35 PCS 5/16"-18 x 5" Grade 5 Plain Finish Hex Cap Screw SUPPLIED UNDER OUR TRACE NUMBER 220023859 AND UNDER PART NUMBER 12073

This is to certify that the above document is true and accurate to the best of my knowledge.

Fastenal Account Representative Signature

Ashly Stanczyk

Printed Name

7/6/18

Date

Please check current revision to avoid using obsolete copies.

This document was printed on 07/06/2018 and was current at that time.

Fastenal Store Location/Address

3201 N. 23rd Street STE 1
LINCOLN, NE 68521
Phone #: (402)476-7900
Fax #: 402/476-7958

Page 1 of 1

Figure B-3. $^{5}/_{16}$-in. (8-mm) Plain Hex Head Bolt Material Certification

QUALITY CERTIFICATE

NINGBO JINDING FASTENING PIECE CO., LTD

XIJINGTANG JIULONGHU NINGBO CHINA TEL:+86-574-86530122 FAX: +86-574-86530858

Customer:	FASTENAL COMPANY PURCHASING--IMPORT	Date :	2015-01-16
Product:	HEX CAP SCREWS	Contract No:	14JDF599T
Class:	5	Invoice No:	00331096-5
Size:	5/16-18X5	Lot No:	3321720021
Marking:	JDF three radius	Order No.	120209249
Quantity:	3.330 mpcs	Part No.	11241191
		Production Date	2014-10-11
Dimensions Of SPEC:		Certificate No.:	20141024430

Inspection Items		Standard	Result	Sample	Pass
Visual Appearance		--------------	OK	22	22
Body Diameter		0.313-0.307	0.309-0.308	4	4
Thread	Go	3A	OK	15	15
	No Go	2A	OK	15	15
Width Across Flats		0.500-0.489	0.491-0.493	4	4
Width Across Corners		0.577-0.557	0.567-0.571	4	4
Major Diameter		0.311-0.303	0.309-0.310	15	15
Head Height		0.211-0.195	0.202-0.205	4	4
Total Length		5.000-4.902	4.965-4.969	15	15
Thread Length		min 0.875	0.925-0.936	15	15
Key Engagement		/	/		
Head Diameter		/	/		
Mechanical Properties					
CharacTeristics		Standard	Result		
Surface Hardness	[30N]	MAX 54	41-43	15	15
Core Hardness	[HRC]	25-34	26-27	15	15
Wedge Strength	[psi]	min 119880	130765-136860	4	4
Yield Strength	[psi]	min 91869	102899-110011	4	4
Elongation	[%]	min 14	16.0-17.6	4	4
Reduction Of area	[%]	min 35	42.4-50.0	4	4
Proof Load	[Ib]	4450	4450	4	4
Impact test -20℃	[Akv/J]	/	/		
Decarburization		N≥1/2H1 HV0.3	300.85 300.85 307.15	4	4
HV2>=HV1-30, HV3<=HV1+30		G 0.0006max			
CHEMICAL COMPOSITION(%)					

Heat No		C	Si	Mn	P	S	Cr	Ni	Cu	Mo	B
XG40ACR	321404604	0.42	0.17	0.73	0.014	0.004	0.28				
Thickness	[UM]									20	20
Surface Coating:		GEOMET									

Thread Specification: ASME B1.1 2008, UNIFIED INCH SCREW THREADS(UN AND UNR THREAD FORM)

Sampling Dimension Specification: ASME B18.18.2 2011 inspection and quality assurance for high-volume machine assembly

Dimension Specification: ASME B18.2.1 2012, HEX CAP SCREWS

Sampling mechanical properties specification: ASTM F1470 2012 Standard Guide for Fastener Sampling for Specified Mechanical

Mechanical Properties: SAE J429 2013, MECHANICAL AND MATERIAL REQUIREMENTS FOR EXTERNALLY THREADED FASTENERS

Surface Defect: ASTM F788/F788M, SURFACE DISCONTINUITIES OF BOLTS, SCREWS, AND STUDS

Plating Specification: ASTM 1941 2010, Electrodeposited Coatings On Threaded Fasteners

Quality Control Supervisor	Quality Control Manager

NINGBO JINDING FASTENING PIECE CO., LTD INSPECTION DEP
宁波金鼎紧固件有限公司质检科

Figure B-4. $^{5}/_{16}$-in. (8-mm) Dia. Ecoguard Hex Head Bolt Material Certification

Appendix C. Test Results

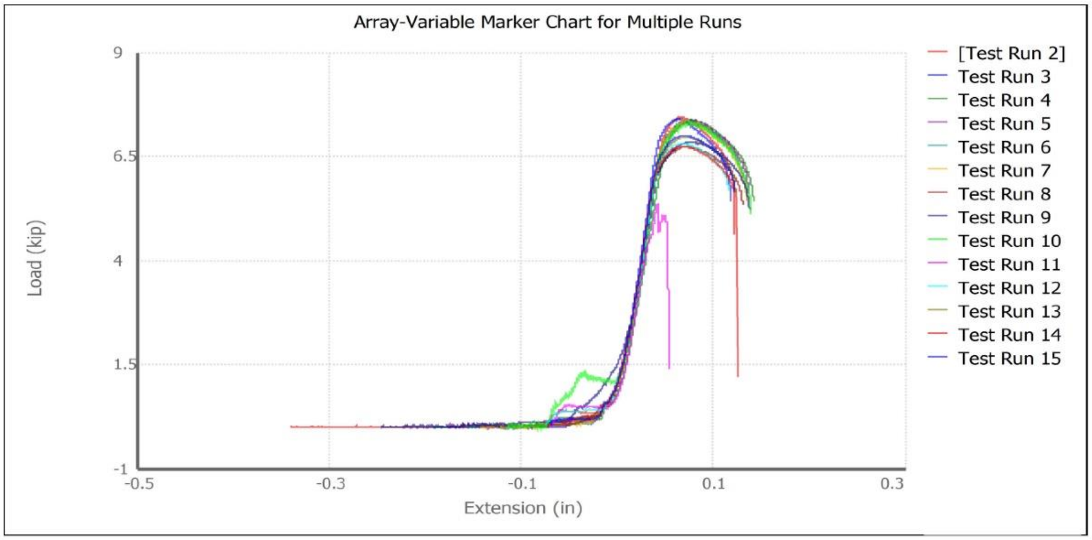
1 - 1 10/5/2018

MTS STH ASTM F606 Full-Size Product of Externally Threaded Fasteners Tension-Default Test Report2

Default Test Report

Project Name	**Project 1**
User Name	**MTS**
Test Name	
Test Date	**7/9/2018 9:55:08 AM**

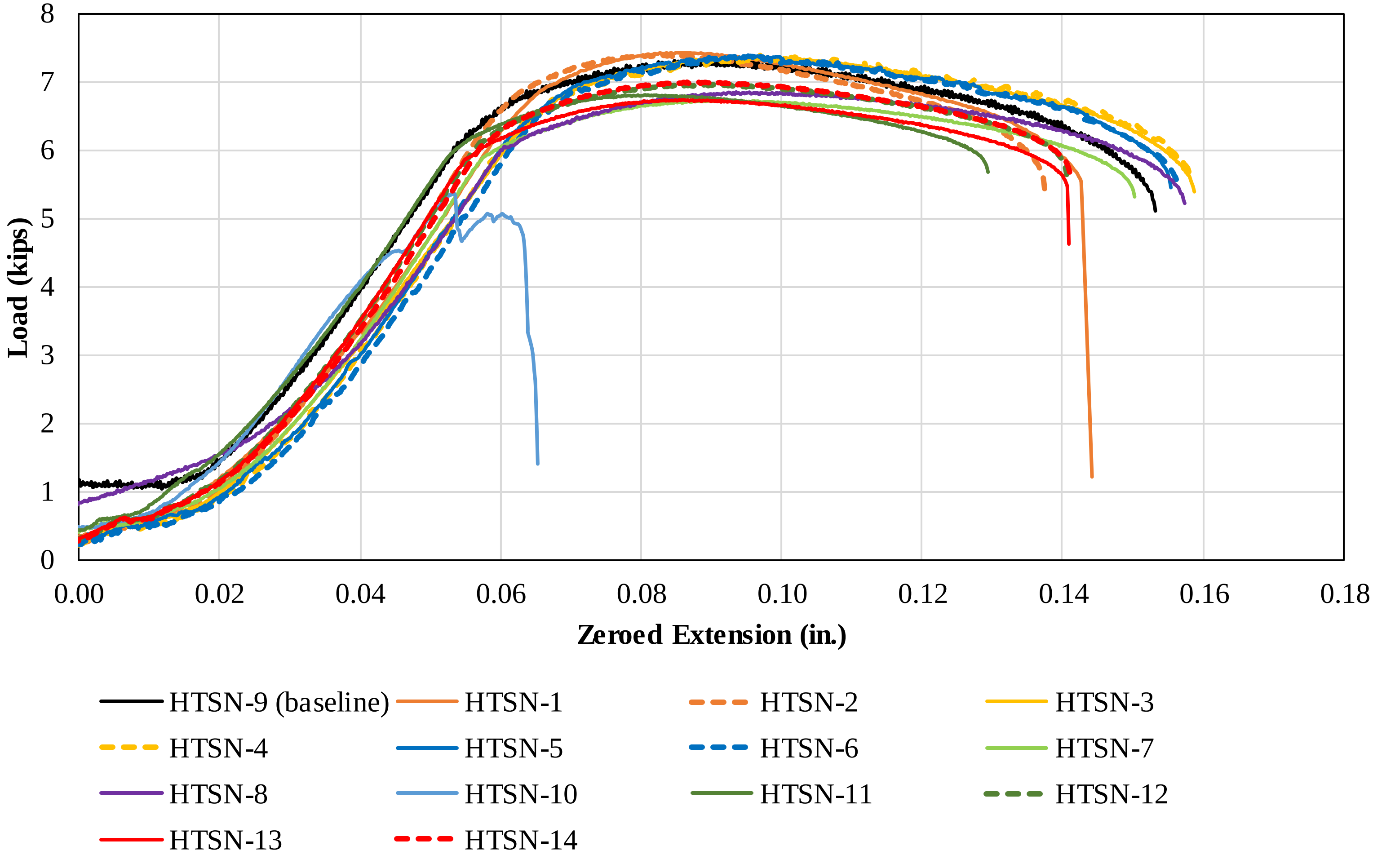
All Test Runs Chart



Test Run Results

Name	Tagged	Load at Tensile Strength (kip)	Tensile Strength (kip/in²)	Test ID
Test Run 2	No	7.433	141.8	HTSN-1
Test Run 3	No	7.401	141.2	HTSN-2
Test Run 4	No	7.374	140.7	HTSN-3
Test Run 5	No	7.392	141.1	HTSN-4
Test Run 6	No	7.396	141.2	HTSN-5
Test Run 7	No	7.382	140.9	HTSN-6
Test Run 8	No	6.736	128.5	HTSN-7
Test Run 9	No	6.855	130.8	HTSN-8
Test Run 10	No	7.338	140.0	HTSN-9
Test Run 11	No	5.368	102.4	HTSN-10
Test Run 12	No	6.813	130.0	HTSN-11
Test Run 13	No	6.965	132.9	HTSN-12
Test Run 14	No	6.740	128.6	HTSN-13
Test Run 15	No	7.001	133.6	HTSN-14
	Mean	7.014	133.9	
	Standard D	0.549	10.5	

Figure C-1. MTS Test Results Summary



Load (kips)
Zeroed Extension (in.)
0
1
2
3
4
5
6
7
8
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
HTSN-9 (baseline)
HTSN-1
HTSN-2
HTSN-3
HTSN-4
HTSN-5
HTSN-6
HTSN-7
HTSN-8
HTSN-10
HTSN-11
HTSN-12
HTSN-13
HTSN-14

END OF DOCUMENT